Determining an Optimal Default CD Gain

Cory V. Dahn

Department of Computer Science

Colorado State University

cory.dahn@rams.colostate.edu

*****Abstract*****

Keywords and Phrases: CD Gain, Sensitivity, Mouse, Touchpad, Optimal CD Gain, Optimal Sensitivity

1 INTRODUCTION

Like many subjects in human-computer interaction, cursor sensitivity is one that will remain unnoticed if set optimally, yet provide a constant, noticeable annoyance if set in a suboptimal way.

Prior research on the subject has found that there is an optimal CD gain level for mice. However, there is little to nothing that concerns the optimal level for touchpads, neither is there much discussion about which CD gain levels feel most natural to users.

Therefore, the purpose of this research is to verify the findings of previous research into CD gain for mice and to determine an optimal CD gain for touchpads.

2 LITERATURE REVIEW

Previous research into optimal CD gain began decades ago. From this, Fitts' Law was developed. Fitts' Law has been instrumental in prior studies into optimal CD gain.

Fitts' Law is a core aspect that influences optimal control-display (CD) gain levels. It pertains to CD gain through its model for cursor movement time (MT) with respect to movement difficulty (MD), with two constants a and b that can be determined through linear regression [6].

$$MT = a + b(MD)$$

Fitts' Law was applied in the analysis of the effectiveness of various pointing devices, including a trackball mouse and touchpad [4]. The mouse was able to acquire targets much faster than the touchpad, more so as the difficulty to acquire the target increased [4]. Two experiments [2, 5] attempted to determine optimal CD gains with mice. One [2] was unable to determine an optimal gain, while the other [5] determined that gains of 2.4 for display movements of 40mm and 14.5 for

display movements greater than 40mm minimized MT. However, this says nothing about accuracy or user preference.

Nevertheless, those conclusions [5] raise the question of the effect display movement distance has on optimal gain. Lower control gains favor shorter distances and higher distances favor higher gains, given the reduced movement speed [10]. However, both longer movement distances and shorter movement times results in higher rates of overshooting the target [3].

Given that people of all ages are using computers and that people of different ages have different physical capabilities, it is useful to consider age when determining optimal gain. When studying the effects of various levels of gain on young adults (24 – 29 years) and the elderly (61 – 68 years) [7], however, it was discovered that both the young and elderly groups' optimal CD gain was 4, despite the elderly group's increased muscle activation when manipulating the mouse. When dealing with young children inexperienced with mouse use, no special considerations must be made. Children are just as capable with minimizing movement time at higher CD gains as young adults, but a gain of 4 facilitated the greatest accuracy [1]. Since all age groups' optimal CD gain is 4, it leads one to believe that no special considerations must be made for age.

It is important to consider the user's perception of the effect CD gain has on cursor movement. When using a stylus [8], users were most effective at matching their hand movement with cursor movement at very low gain levels (≤1). The minimum gain to retain that synthesis was 0.4 [8]. This is likely explained by the similarity the stylus has with the touchpad in terms of input method, which favors slow, precise movements [9]. With mice, however, users tended to prefer a gain of 4 [3].

Overall, previous research has found that a CD gain ratio of 4 is optimal for all age groups when a mouse is used. There is no difference between age groups.

However, it is not clear if there is any difference when a touchpad is used. The most preferred CD gain level for each device according to the existing literature is also unclear.

3 EXPERIMENT DESIGN

Given the lack of research and adequate software necessary to answer the questions this paper seeks to answer, it was necessary to develop a testing program. The program was developed in Unity Game Engine 2019.4.19f1 and involves clicking a series of targets. The program runs in a fixed resolution of 1024x768 to preserve the various CD gains tested.

In this program, the subject is first presented with a description of the experiment and a series of instructions. Due to being forced into remote testing, the subject is also provided with instructions on how to report their results (by emailing a series of files and the CD gain level that felt most natural to them to a given email address).

Part of these instructions directs the subject to modify cursor sensitivity levels both in their systems' settings and in any "DPI-controlling" software their mouse may have. In the latter case, subjects were instructed to set this to 1600, since most mice without variable DPI capabilities operate at 1600 DPI. This was to encourage standardized settings across a range of systems and peripheral device configurations.

When the subject begins testing, they are placed in a tutorial segment designed to acclimate them to the experiment. Nothing that occurs during this segment is recorded.

During the tutorial, the subject is presented with a series of blue spheres on which they are directed to click by placing the center of the screen (marked by a red dot) over the applicable target. Once a target is successfully clicked, it is moved to some randomly chosen position within the enclosed virtual environment. After the target is clicked for the tenth time, the tutorial ends and the first testing level begins. The CD gain is set to 2, which is not one of the tested levels so as to avoid acclimating the subject to any particular CD gain level.

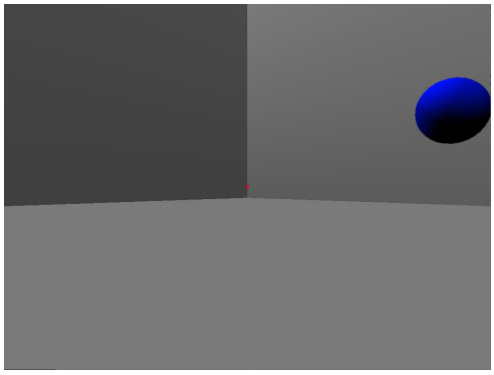

Figure 1: The tutorial environment with the red dot for aiming and the blue target

After the tutorial, subjects were directed to perform the task with five levels of CD gain – **1.0**, **2.5**, **4.0**, **5.5**, and **7.0**. These values were chosen because previous research indicated that 4 was the optimal CD gain ratio. To mitigate legacy bias, these levels were associated with unique, arbitrarily chosen words from several categories – ***Inkwell***, ***Switzerland***, ***Pine***, ***Table***, and ***Horse***, respectively. They were presented to the subject in a pseudorandom to prevent the subject from getting used to any recognizable change in CD gain.

Given the arbitrary nature of the words, it was important that they were made memorable. This was done by associating the CD gain level with both the term and its category. Subjects were therefore able to remember either the term itself or the category, if they forgot the term.

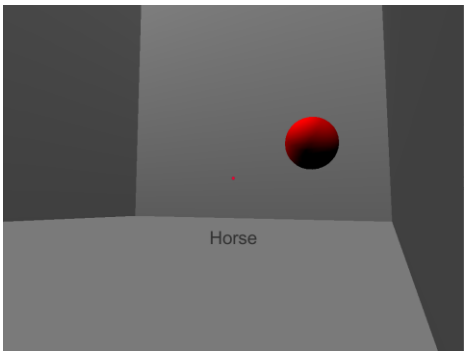

Figure 2: One of the environments for testing one of the CD gain levels. This particular environment tests a CD gain of 7.0, which is noted by the keyword Horse instead of the number itself. In all testing environments, the targets are red rather than blue.

At the end of each test, the subject's accuracy (defined by the number of targets, 10, divided by the number of attempted clicks) and the average time to click each target are each written to a file that is saved in the directory in which the test's executable resides. Once the entire experiment is complete, there will be ten saved files. Along with the user's self-reported most natural-feeling CD gain level, these files are submitted by the individual subject via email.

4 RESULTS

Out of twelve participants, six reported using mice and six reported using touchpads.

Table 1: Self-reported Accuracies per Gain Level

1.0	2.5	4.0	5.5	7.0	Device
0.769	0.833	0.909	0.833	0.909	Mouse
0.909	1.000	0.833	0.833	0.667	Mouse
0.909	1.000	0.909	0.909	0.833	Mouse
0.909	0.909	1.000	1.000	0.833	Mouse
0.714	0.769	0.714	0.769	0.909	Mouse
1.000	0.909	1.000	1.000	0.833	Mouse
0.833	0.833	0.909	0.909	1.000	Touch
0.833	0.909	0.833	0.714	0.588	Touch
0.909	0.769	0.769	0.769	0.455	Touch
0.714	0.769	0.909	1.000	1.000	Touch
0.667	0.909	0.909	0.833	0.063	Touch
0.833	0.833	0.833	0.833	0.588	Touch

Table 2: Self-reported Average Times-to-Click per Shot per Gain Level

1.0	2.5	4.0	5.5	7.0	Device
1.717	1.911	2.417	2.373	2.273	Mouse
1.335	1.397	2.137	3.263	3.481	Mouse
1.485	1.501	1.412	1.589	3.007	Mouse
1.888	1.482	2.013	4.092	6.990	Mouse
1.901	2.198	1.943	1.943	2.177	Mouse
2.256	1.170	1.130	1.080	1.526	Mouse
1.575	1.700	1.543	1.758	2.093	Touch
2.736	2.457	3.451	2.700	4.407	Touch
5.629	2.731	2.321	2.835	9.544	Touch
2.687	2.103	2.183	2.271	2.666	Touch
2.082	1.399	1.283	1.693	2.009	Touch
2.942	2.078	2.156	2.251	2.794	Touch

An ANOVA performed on the accuracies and average times given CD gain level shows that these values are significantly different from one another ($p = 0.001$).

Table 3: Average Accuracy (ACC) and Time-to-Click (TTC, in seconds) per Gain Level

		1.0	2.5	4.0	5.5	7.0
Mouse	**ACC**	.868	**.903**	.894	.891	.831
	TTC	1.76	**1.61**	1.84	2.39	3.24
Touch	**ACC**	.798	.837	**.860**	.843	.616
	TTC	2.94	**2.08**	2.16	2.25	2.8

The highest accuracy and the shortest average time in each row are bolded and underlined

According to the averages calculated in table 3, 2.5 is the optimal CD gain ratio for both mice and touchpads. The only value for which 2.5 was not optimal was the touchpad's accuracy, which was only 2.7% less optimal than the optimum of 4.

In addition to raw statistics like those, user preference should also be considered when determining which level is optimal.

Table 4: Self-reported Gain Level Preferences

Mouse	Touchpad
4.0	5.5
4.0	5.5
5.5	2.5
2.5	N/A
4.0	4.0
4.0	N/A

"Which CD gain level felt most natural to you?" – Responses

However, a Mann-Whitney U test performed on these self-reported preferences shows that there is no significant difference between the values recorded ($p = 0.575$).

5 SHORTCOMINGS

There are several areas for improvement in this experiment. They range from preparation for the experiment to conduct of the experiment.

First, that the experiment had to be conducted remotely posed many challenges. Not only did the subjects have to set up the experiment on their own, but they had to report their own results too. It is possible that some subjects did not set up their system's sensitivity correctly, or that they misreported their results intentionally or mistakenly.

Another potential problem was the test program's interaction with touchpads. Some of the subjects mentioned not being able to tell a difference between the different CD gain levels. The program's modifications to CD gain may have something preventing them from making any noticeable modification to a touchpad's CD gain.

The most serious problem is the number of subjects. There were only six subjects that used each pointing device. More reliable results could have been gotten with at least twenty subjects, ten per device.

6 CONCLUSIONS

According to the findings detailed herein, the hypothesis that confirmed previous research – that 4.0 is the ideal CD gain – has proven to be incorrect.

This may have wide-reaching implications in human-computer interaction, potentially affecting both hardware and software design. Not only could it apply to mouse and touchpad design, but also to the design of software ranging from operating systems to video games.

However, it would be beneficial for this research to be replicated in the future before any final judgment on the quality of this research may be rendered. It would be especially useful to address the previously discussed shortcomings, especially in a controlled setting using only one system to administer the tests.

REFERENCES

[1] Ahlström D, Hitz M. Revisiting PointAssist and Studying Effects of Control-Display Gain on Pointing Performance by Four-Year-Olds. IDC '13: Proceedings of the 12th International Conference on Interaction Design and Children, pages 257-260, 2013.

[2] Arnaut L. An evaluation of display/control gain in the context of control-display interface optimization. Doctoral dissertation, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 1986.

[3] Casiez G, Vogel D, Balakrishnan R, Cockburn A. The Impact of Control-Display Gain on User Performance in Pointing Tasks. Human-Computer Interaction, 23:pages 215-250, 2008.

[4] Epps B. Comparison of six cursor control devices based on Fitts' Law models. Proceedings of the Human Factors Society 30th Annual Meeting, pages 327-331, 1986.

[5] Hang Pang Y, Hoffmann E, Goonetilleke R. Effects of Gain and Index of Difficulty on Mouse Movement Time and Fitts' Law. IEEE Transactions on Human-Machine Systems, 49(6):pages 684-691, 2019.

[6] MacKenzie, I. Human-Computer Interaction: An Empirical Research Perspective. Waltham, MA: Elsevier, 2013, pages 249-252.

[7] Sandfeld J, Jensen B. Effect of computer mouse gain and visual demand on mouse clicking performance and muscle activation in a young and elderly group of experienced computer users. Applied Ergonomics. 36:pages 547-555, 2015.

[8] Sutter C, Müsseler J, Bardos L, Ballagas R, Borchers J. The impact of gain change on perceiving one's own actions. Mensch & Computer, pages 147-156, 2008.

[9] Sutter C, Ziefle M. Psychomotor performance of input device users and optimized cursor control. Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting, pages 742-746, 2006.

[10] Thompson S, Slocum J, Bohan M. Gain and Angle of Approach Effects on Cursor-Positioning Time with a Mouse in Consideration of Fitts' Law. Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting, pages 823-827, 2004.